Bonneville

Redistribution Of Salt By Pond Migration, Bonneville Salt Flats, Western Utah

Problem: The BLM is concerned that a potentially significant form of salt loss from the Bonneville Salt Flats is by wind-driven surface ponds during winter months. These surface ponds, which are composed of brine, can be blown over to the area influenced by the brine-collection ditches and infiltrate into the subsurface. Also, during spring months, salt can be deposited in this same area by evaporation of the surface ponds and precipitation of salt on the mud-flat surface. This salt could then be dissolved by direct rainfall and subsequently infiltrate into the subsurface. The BLM would like to know the quantity of salt transported by this mechanism and to have a method by which this process could be monitored in the future.

The changing areal extent of the salt crust is a dynamic process that depends largely on short and long-term climatic changes. Any estimates of salt transport by surface ponds are only approximations that involve snapshots in time and many simplifying assumptions. These estimates should only be used to determine the relative significance of this process in the overall salt budget for the Bonneville Salt Flats. Depending on yearly climatic conditions, this process might be more significant in some years than others.

Hydrologic Processes: The surface ponds form in the late fall, most likely as a result of the rising water table. When evaporation ceases or becomes negligible, brine from the shallow-brine aquifer gradually accumulates on the surface of the salt crust where it can be transported by wind. There is no evidence to support the concept that the ponds are formed by precipitation either as direct rainfall on the surface or as surface runoff from the Silver Island Mountains. However, direct precipitation will add to the volume of the ponds and can dilute the brines to the point where dissolution of salt might occur.

With this concept of pond formation in mind, the question may arise as to what area of the salt crust does the brine originate, or what percentage of the brine is derived from private or leased property? This can be estimated by defining the overall area that might contribute brine to the surface ponds and then determine what percentage of this area is private or leased. The contributing area can be defined by delineating the area where the water table is within a specified distance below land surface during the fall before ponds begin to form. The percentage is then applied to the volume of the surface ponds to determine the amount of salt that might be derived from private or leased property.

During the winter months, the surface ponds are moved in the direction of the prevailing winds. These ponds might move several hundred yards or even a few miles within a matter of a hours with changing wind direction. With the possible rapid movement of surface ponds, tracking the movement of the ponds is not feasible or practical.

The two methods of salt deposition within the area of influence of the collection ditches, infiltration of brine and deposition of salt through evaporation, should be the primary emphasis rather than merely tracking the migration of ponds. Infiltration rates need to be estimated for the carbonate mud between the salt crust and the collection ditches. By knowing the infiltration rate and estimating the length of time surface ponds are in this area, the quantity of brine infiltrating into the shallow-brine aquifer can be estimated. Turk and others (1973, p. 73) estimated infiltration for the carbonate muds to be 0.4 to 1.4 ft/d. Lines (1979, p. 85) stated that even the infiltration rate of 0.4 ft/d is probably high. At best, Lines thought that infiltration rates are probably 10 percent of those for the salt crust, thus ranging, at most, from 0.25 to 0.4 ft/d. On the basis of these rates, Lines (1979, p. 86) estimated that 2,000 acre-ft infiltrated into the carbonate mud. Tritium values from brine collected from six wells along the north line of wells between the salt crust and the collection ditch suggest that the quantity of brine from the surface ponds infiltrating through the carbonate mud into the shallow-brine aquifer might not be a significant (see figure). The higher tritium values, reported in tritium units (TU), indicate older post-bomb water. Additional sampling and tritium analyses are needed to define this relation.

The other method of salt transport into the area of influence of the collection ditches is by deposition of salt onto the carbonate-mud surface upon evaporation of ponds in the spring and early summer and the possible dissolution of the salt by direct rainfall and its subsequent infiltration. An estimate of this quantity of salt might be derived by examining satellite images in the fall, just prior to pond formation, and in early summer after the ponds have disappeared and a new crust has been formed.

Approach: Infiltration of brine from surface ponds, if it is occurring to a significant degree, would be the more complex of the two processes to quantify. Evidence from tritium analyses, mentioned previously, suggests that infiltration may not be a significant process. To verify this hypothesis, three additional, hand-augered wells need to be installed adjacent to existing deeper wells on the east end of the north line of wells (see figure). These wells will be completed at a depth such that only water near the water-table surface will sampled. The brine will be analyzed for tritium and compared to values obtained for brine from the deeper, adjacent wells. If the new tritium values are similar, then the hypothesis for no significant infiltration in this area might be substantiated with further analysis pertaining to probable dispersion values and the radioactive decay rate for tritium. Additional tritium samples would have to be collected at other locations between the salt crust and the collection ditch in order to corroborate this hypothesis throughout this area.

If the new tritium values range from 15 to 25 TU, then infiltration would appear to be significant process for placing salt into a pathway for migration to the collection ditch. As a result, an estimate for infiltration is neccessary for calculating total infiltration during winter months. One method for estimating infiltration rates would be to collect cores for geotechnical analyses. By determing a vertical profile for moisture content, moisture retention, and saturated hydraulic conductivity, and using the Variably Saturated Two-Dimensional Model, the rate of infiltration can be estimated. The disadvantage with this method is the inability to compensate for retarded infiltration if surface clays expand as a result of hydration of the clay matrix.

Surface clays need to be sampled and identified by X-ray defraction to determine the presence of smectite. If smectite does not comprise a significant amount of the surface clays, then retardation as a result of expansion of surface clays not be a factor in determining infiltration rates.

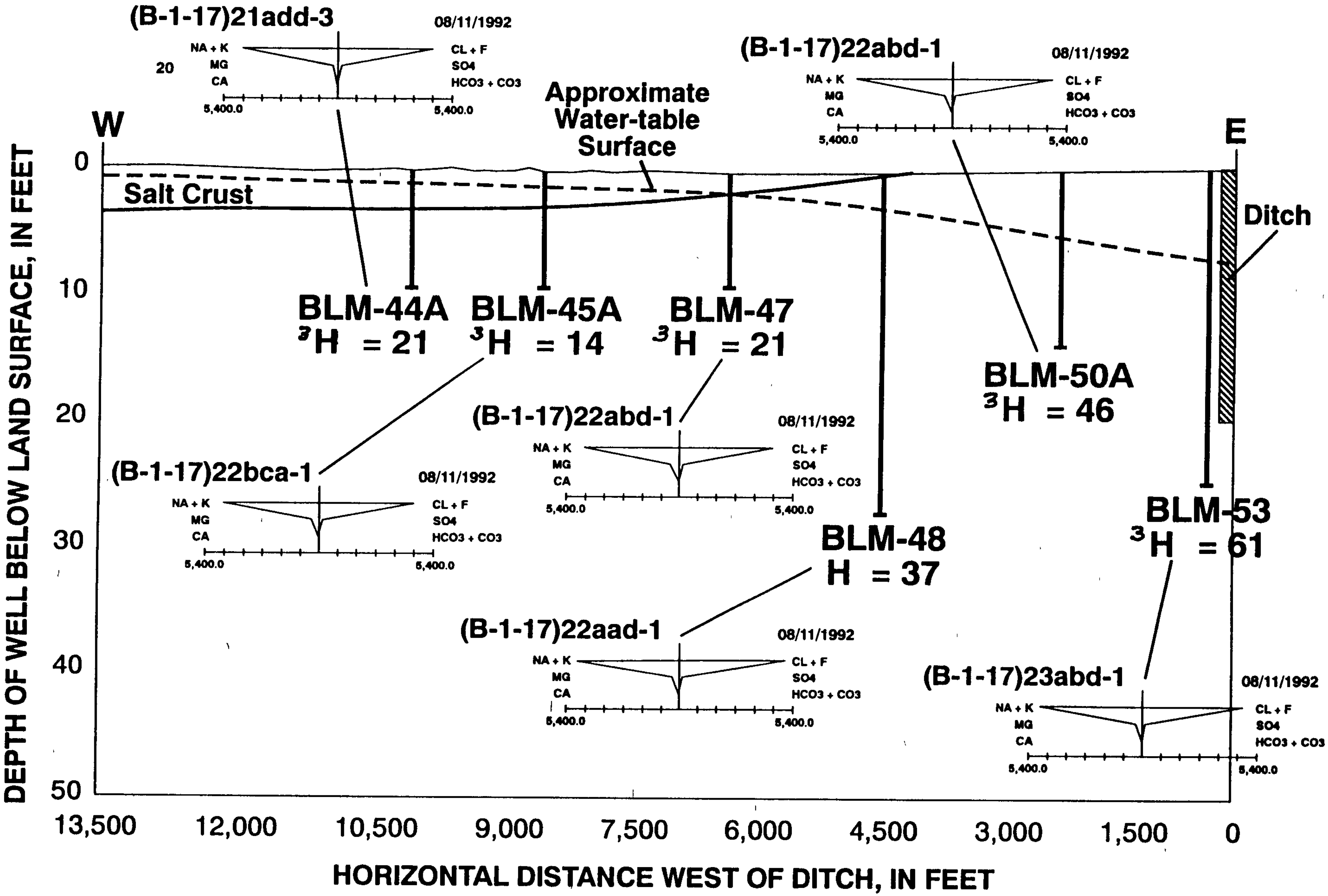
An alternative method would be to measure actual infiltration in situ. This could be accomplished by an actual field experiment in which brine is placed at the surface and its infiltration is measured by nested tensiometers; however, most field methods of this type, such as the instantaneous profile method, allow the sample water to infiltrate fully and the water content of the soil is measured by the tensiometers as the water moves downward. As with the previous method, the retardation at the surface is not included. Therefore, if retardation does occur at the surface, the field method selected must be able to compensate or measure this retardation.

Estimating the quantity of salt deposited on the surface upon pond evaporation in the spring would require knowing the areal extent of the salt crust in the fall prior to pond formation and knowing the areal extent of the salt crust after pond evaporation. Any increase in the areal extent of the salt crust between the main part of the salt crust and the collection ditches to the east could be attributed to pond migration assuming all the new salt deposited is from the ponds and not from evaporation of brine within the playa mud. By assuming an average thickness based on field measurements of the newly deposited salt crust, the volume can be estimated.

References Cited

Lines, G.C., 1979, Hydrology and surface morphology of the Bonneville Salt Flats and Pilot Valley playa, Utah: U.S. Geological Survey Water-Supply Paper 2057, 107 p.

Turk, L.J., Davis, S.N., and Bingham, C.P., 1973, Hydrogeology of lacustrine sediments, Bonneville Salt Flats, Utah: Economic Geology, v. 68, p. 65-78.



W
E
DEPTH OF WELL BELOW LAND SURFACE, IN FEET
HORIZONTAL DISTANCE WEST OF DITCH, IN FEET
Approximate Water-table Surface
Salt Crust
Ditch
BLM-44A ^3H = 21
BLM-45A ^3H = 14
BLM-47 ^3H = 21
BLM-48 H = 37
BLM-50A ^3H = 46
BLM-53 ^3H = 61
(B-1-17)21add-3 08/11/1992
(B-1-17)22abd-1 08/11/1992
(B-1-17)22bca-1 08/11/1992
(B-1-17)22abd-1 08/11/1992
(B-1-17)22aad-1 08/11/1992
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NA + K
MG
CA
CL + F
SO4
HCO3 + CO3
5,400.0
20
0
10
20
30
40
50
13,500
12,000
10,500
9,000
7,500
6,000
4,500
3,000
1,500
0

PROGRESS AND PLANS FOR BONNEVILLE SALT FLATS STUDY,
NOVEMBER, 1992, THROUGH JANUARY, 1993

February 2, 1993

Progress:

Because of the above average precipitation, no significant fieldwork has been completed since the previous TRC meeting. Numerous field activities are planned and will be pursued when conditions permit.

Water levels have been contoured for the June-July, 1992, measurement period (see figure). Water levels were corrected to an average density for the data set. Not all data points were used in the map because of the lack of elevation control. Generally, this map is similar to those presented by Lines (1979).

Pore fluids have been extracted from cores collected during October. Larger intervals were used for extraction rather than the small intervals used in previous cores. Because of the uniformity in chemical analyses from the previous cores, these samples were used to for spatial variations. At the time of this report, no results have been received.

Tim Lowenstein from State University of New York, Binghamton, New York, has looked at the salt cores and will analyze fluid inclusions within individual salt crystals. These fluids will be analyzed for major-ion chemistry and oxygen-18 and deuterium isotopes. From these results, hopefully, interpretations of the crystallization process can be made.

Comparisons of chemical analyses from well fluids and pore fluids reveal that generally the pore fluids have higher concentrations of potassium and magnesium than do the well fluids. This is evidence that would support the dual porosity nature of the shallow-brine aquifer. Also, the pore fluids within the tighter porous medium might be a continual source of potassium and magnesium to the more mobile brines within the fractures.

Potassium data have been plotted and contoured (see figure). Although the data set is incomplete, the contour map shown is virtually identical to the map presented by Lines (1979, p. 95). The only difference being the higher concentration of potassium within the Salduro loop.

Modeling progress is presented later in this report.

Plans for the future:

Measure water levels at a point in time during the winter months when conditions are favorable.

When consistent elevation control has been established, water-level data will be plotted and potentiometric surfaces will be contoured for each set of data.

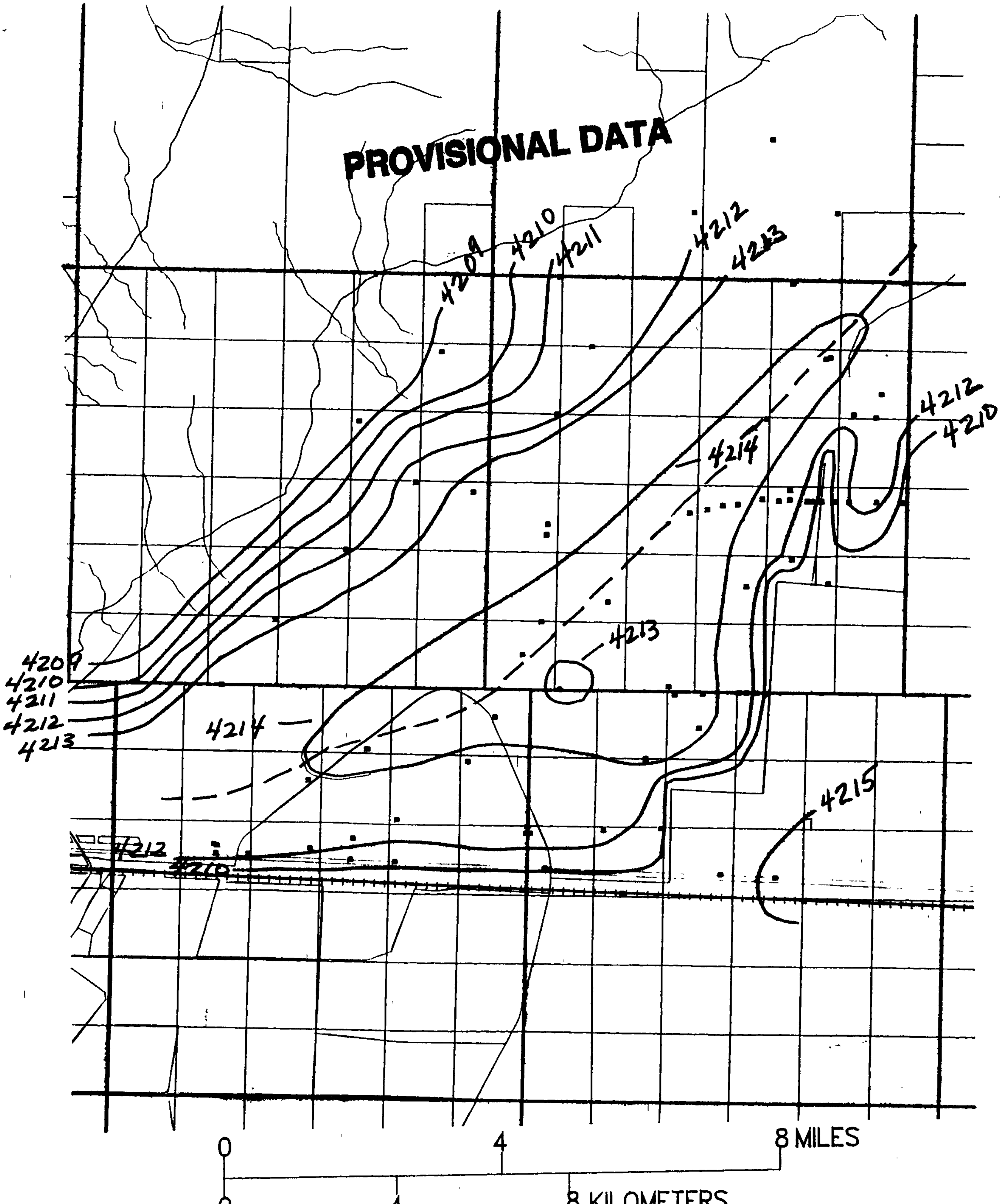
Continue monitoring pump on ditch from federal leases. Make additional discharge measurements.

Collect water samples from the five new observation wells completed in the basin-fill aquifer. Samples will be analysed for major ions and oxygen-18 and deuterium isotopes.

Hand auger three additional wells along north line of wells between salt crust and collection ditch and sample for tritium (see discussion on pond migration included in this packet).

Collect detailed data on density in deep nested well on salt crust.

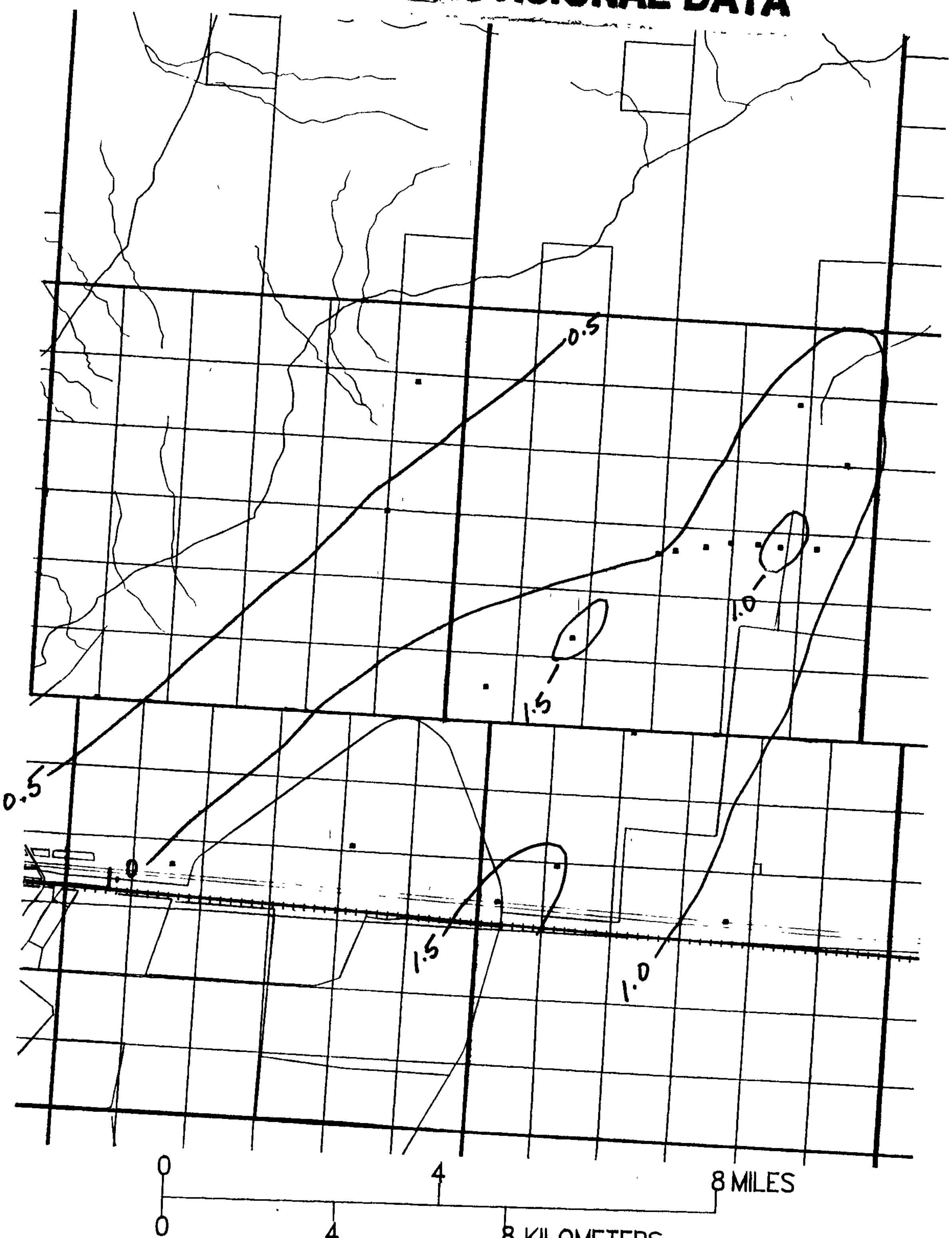
Continue model development.



Water-level contours – Jun and Jul, 1992
Values are feet above sea level

--- Approximate ground-water divide

PROVISIONAL DATA

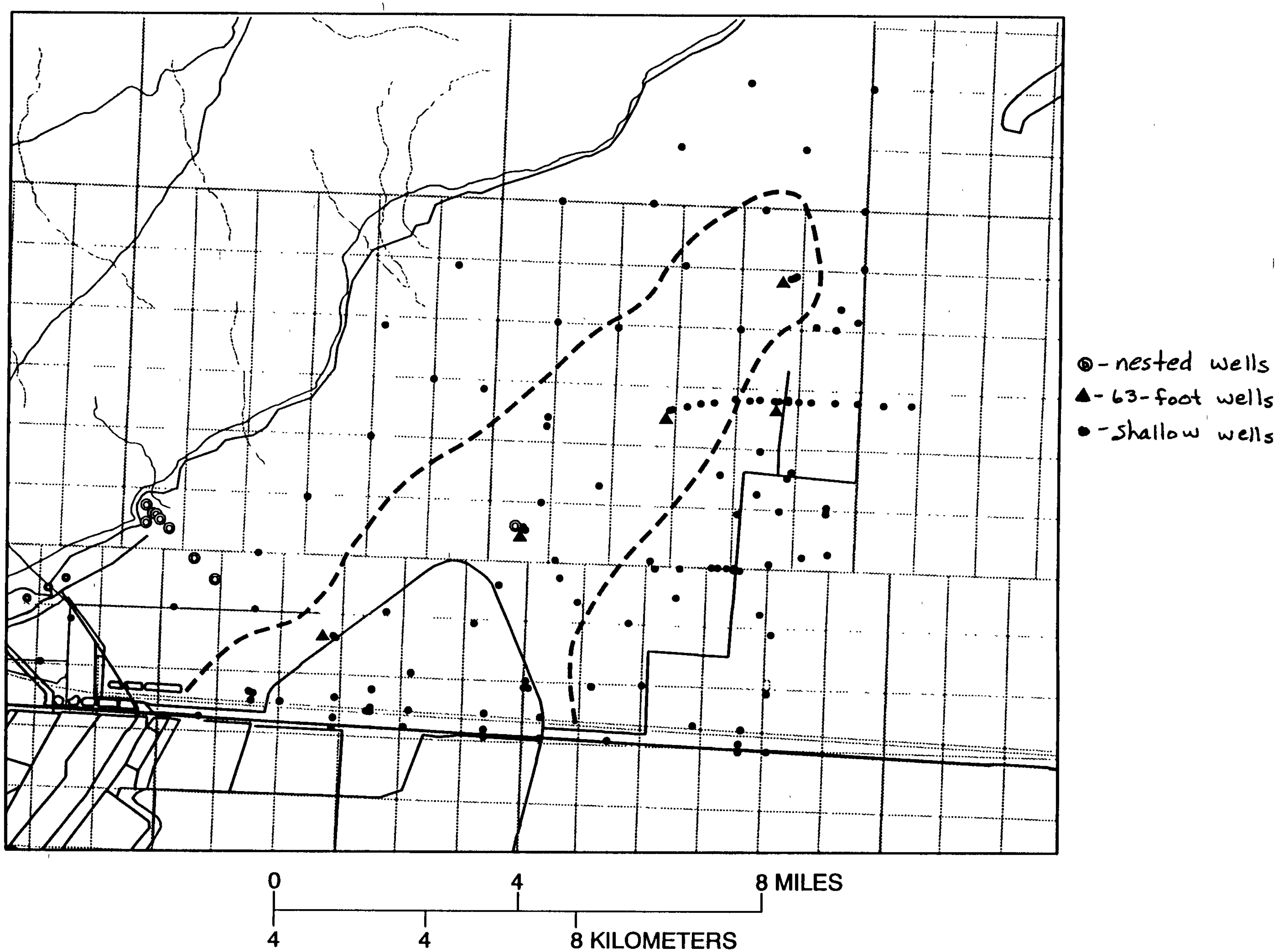


Percent by weight of potassium chloride— Aug and Sep, 1992

Percent KCl by weight

Local Well Number	Lines 1976	1992
(B-1-17) 11aac-1	1.21	1.17
12dbd-1	1.23	1.13
22aad-1	1.26	1.13
24bbd-1	0.44	1.09
29dac-1	1.53	1.59
34ddd-1	1.26	1.22
(B-1-18) 12bab-2	0.33	0.31
23aaa-1	0.60	0.58
(C-1-17) 4bba-1	1.28	1.17
17bba-1	1.47	1.54
(C-1-18) 11ccd-2	0.39	1.28
17bdb-1	1.22	1.08

PROVISIONAL DATA



Hydrologic data sites - locations approximate

MODELING PROGRESS:

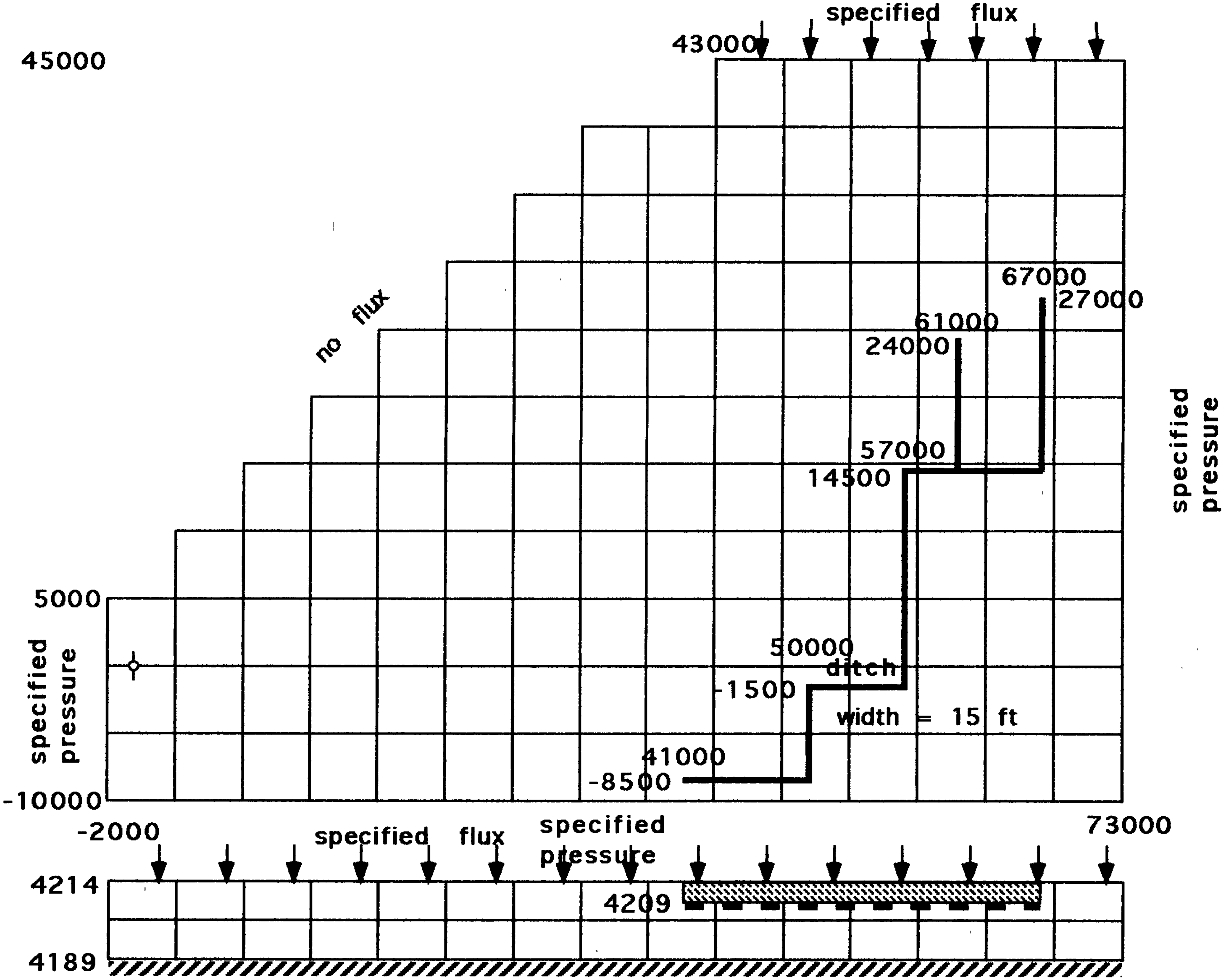
The second version of the simplified three-dimensional flow and transport model was implemented. The region is 75000 ft by 55000 ft by 25 ft. The northwest portion of the region has been set where the salt flats meet the rise of the Silver Island Mountains. The brine production ditch has been represented with a more realistic shape. Boundary condition types and values and aquifer parameter values appear in Figures 1&2. Data were adapted from the Lines(1979) report. This model is of fresh water with incompressible fluid and porous matrix of plastic clay elasticity. Salinity will be introduced when the parameters and boundary condition values have been established at reasonable values. The types of boundary conditions were discussed in the August and November progress reports.

Results of running this model to a steady-state solution appear in Figure 3. Flow rates are shown at each boundary. The flow rate from the ditch is about 1.5 times that given by Lines, but the flow rate through the south boundary is lower by a factor of 5. The water table configuration shows drawdown along the ditch. It also shows high altitudes to the northwest. The northwest boundary was set to be impermeable. The velocity field shows flow from north to south and from the east boundary to the ditch. No groundwater divide, as identified by Lines, appears in this model. A steady-state flow condition is achieved by inflow of brine from the eastern boundary. Lines flow balance showed a decrease of water in storage with time. The low specified pressures along the south boundary produce a large outflow there. However the discharge rate to the ditch is the second highest flow rate after the net precipitation infiltration rate. The ditch flow rate is 60% higher than the previous model due to a reduction in the water level in the ditch.

The results show that much further work is needed to identify and quantify the various boundary conditions. The high altitudes of the water table are believed not to be realistic. The computations for this 500 node simulation region took 6 to 30 minutes on the Masscomp workstation. I have obtained a new Data General 530 workstation that is about 5 times faster. Work continues on the problem that the model does not maintain the concept of uniform inflow and outflow over a given boundary. Subregions of reverse flow occur and there is upflow and downflow at specified pressure boundaries. These effects are due to the difficulty of specifiying an accurate hydrostatic pressure distribution at these boundaries under conditions of compressible matrix and water.

Development continued on an algorithm to handle the cross-dispersive flux terms when the velocity is diagonal across the cells without requiring very small cells. A bug was found in the direct solver that occurs when excluded cells are used causing re-entrant rows. A density and viscosity function for saline water was obtained and is being evaluated for suitability for Bonneville simulations. A review of the pump-test data to look for evidence of dual-porosity flow behavior was begun.

Future work with this model will include: testing alernative boundary conditions at the east and south boundaries; allowing for leakage from the basin fill aquifer through the bottom boundary; and applying a permeability distribution from Lines that includes values from previous work. Sensitivity analyses will be done to evaluate the effects of parameter uncertainty. The solute transport part of the model will be added, but this will require a finer mesh to handle the dispersive terms with reasonable accuracy. The solute transport is not expected to be at steady-state so transient simulations will be done. Designing these simulations will form the third step in refinement of the three-dimensional model. Water level results need to be compared to observed values to continue the calibration procedure.



specified flux
43000
45000
67000
27000
61000
24000
no flux
57000
14500
specified pressure
5000
specified pressure
50000
ditch
-1500
width = 15 ft
41000
-8500
-10000
-2000
specified flux
specified pressure
73000
4214
4209
4189

FIG. 1

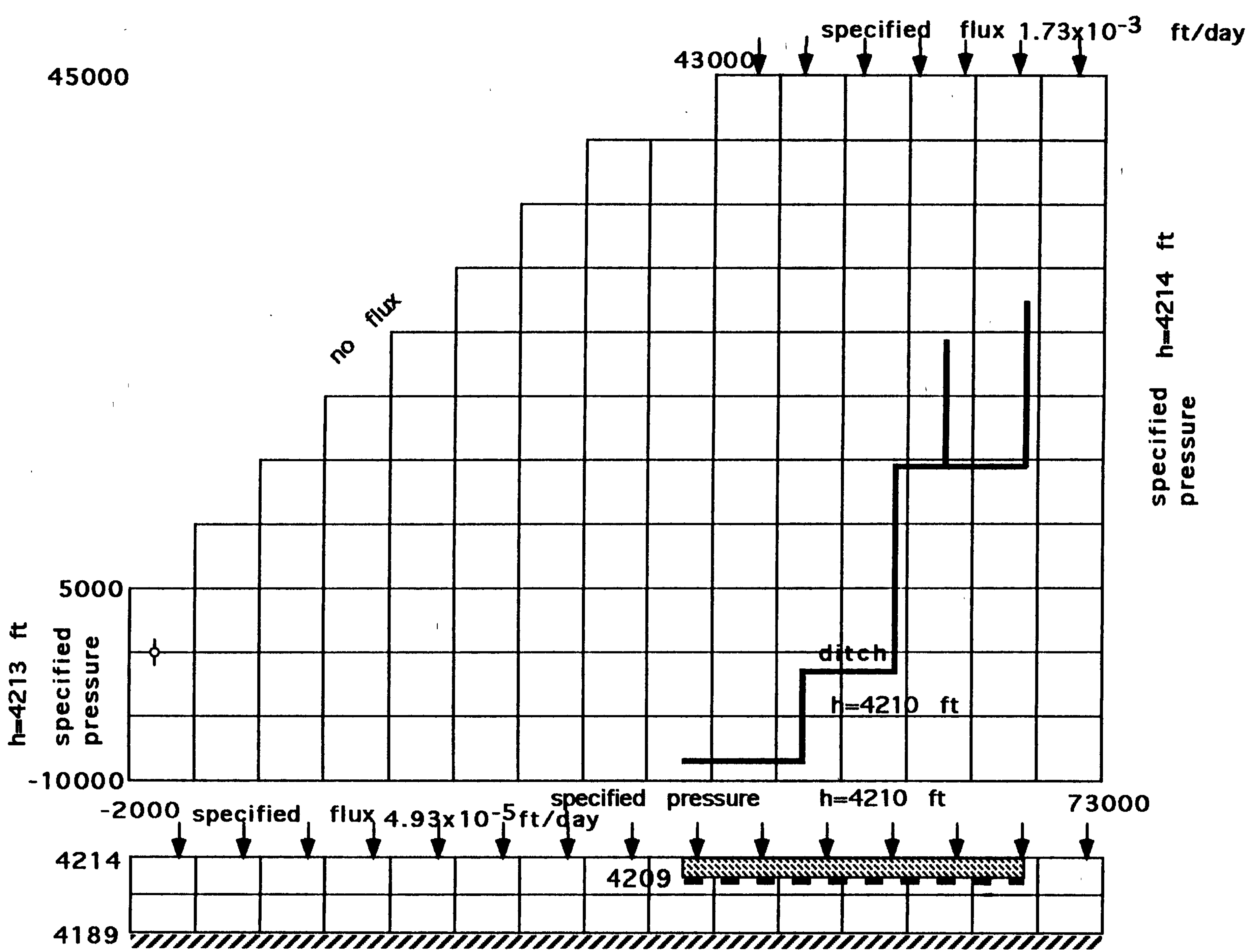

specified flux 1.73x10-3 ft/day
43000
45000
no flux
h=4214 ft
specified pressure
5000
h=4213 ft
specified pressure
ditch
h=4210 ft
-10000
-2000
specified flux 4.93x10-5 ft/day
specified pressure h=4210 ft
73000
4214
4209
4189

FIG. 2

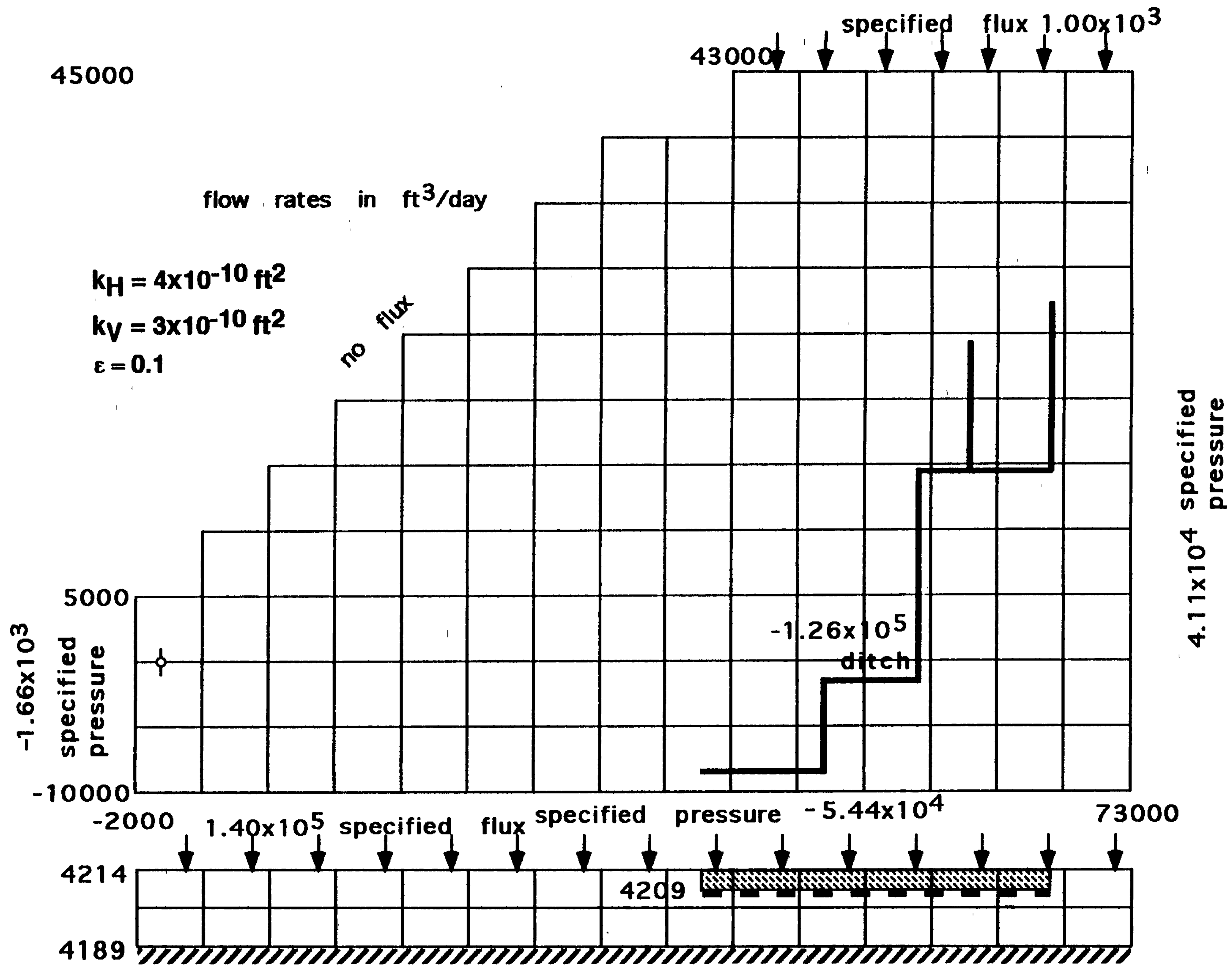

specified flux 1.00x10^3
43000
45000
flow rates in ft^3/day
k_H = 4x10^-10 ft^2
k_V = 3x10^-10 ft^2
ε = 0.1
no flux
4.11x10^4 specified pressure
5000
-1.66x10^3 specified pressure
-1.26x10^5
ditch
-10000
-2000
1.40x10^5 specified flux
specified pressure
-5.44x10^4
73000
4214
4209
4189

FIG. 3